FAIRCHILD SEMICONDUCTOR®

January 2003

# HUFA76413DK8T

## N-Channel Logic Level UltraFET® Power MOSFET 60V, 4.8A, 56mΩ

### General Description

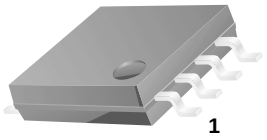
These N-Channel power MOSFETs are manufactured using the innovative UltraFET® process. This advanced process technology achieves the lowest possible on-resistance per silicon area, resulting in outstanding performance. This device is capable of withstanding high energy in the avalanche mode and the diode exhibits very low reverse recovery time and stored charge. It was designed for use in applications where power efficiency is important, such as switching regulators, switching convertors, motor drivers, relay drivers, low-voltage bus switches, and power management in portable and battery-operated products.

### Applications

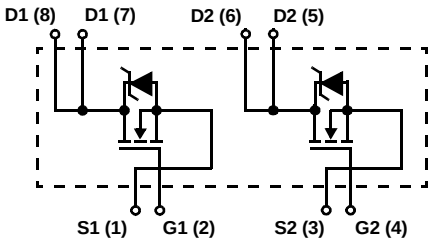
- Motor and Load Control
- Powertrain Management

### Features

- 150°C Maximum Junction Temperature
- UIS Capability (Single Pulse and Repetitive Pulse)
- Ultra-Low On-Resistance $r_{DS(ON)}$ = 0.049Ω, $V_{GS}$ = 10V
- Ultra-Low On-Resistance $r_{DS(ON)}$ = 0.056Ω, $V_{GS}$ = 5V




SO-8




## MOSFET Maximum Ratings $T_A$ = 25°C unless otherwise noted

| Symbol | Parameter | Ratings | Units |
|---|---|---|---|
| $V_{DSS}$ | Drain to Source Voltage | 60 | V |
| $V_{GS}$ | Gate to Source Voltage | ±16 | V |
| $I_D$ | Drain Current<br>Continuous ($T_C$ = 25°C, $V_{GS}$ = 10V) | 5.1 | A |
| | Continuous ($T_C$ = 25°C, $V_{GS}$ = 5V) | 4.8 | A |
| | Continuous ($T_C$ = 125°C, $V_{GS}$ = 5V, $R_{\theta JA}$ = 228°C/W) | 1 | A |
| | Pulsed | Figure 4 | A |
| $E_{AS}$ | Single Pulse Avalanche Energy (Note 1) | 260 | mJ |
| $P_D$ | Power dissipation | 2.5 | W |
| | Derate above 25°C | 0.02 | W/°C |
| $T_J$, $T_{STG}$ | Operating and Storage Temperature | -55 to 150 | °C |

## Thermal Characteristics

| | | | |
|---|---|---|---|
| $R_{\theta JA}$ | Thermal Resistance Junction to Ambient SO-8 (Note 2) | 50 | °C/W |
| $R_{\theta JA}$ | Thermal Resistance Junction to Ambient SO-8 (Note 3) | 191 | °C/W |
| $R_{\theta JA}$ | Thermal Resistance Junction to Ambient SO-8 (Note 4) | 228 | °C/W |

**This product has been designed to meet the extreme test conditions and environment demanded by the automotive industry. For a copy of the requirements, see AEC Q101 at: http://www.aecouncil.com/**

**Reliability data can be found at: http://www.fairchildsemi.com/products/discrete/reliability/index.html.**

**All Fairchild Semiconductor products are manufactured, assembled and tested under ISO9000 and QS9000 quality systems certification.**

## Package Marking and Ordering Information

| Device Marking | Device | Package | Reel Size | Tape Width | Quantity |
|---|---|---|---|---|---|
| 76413DK8 | HUFA76413DK8T | SO-8 | 330mm | 12mm | 2500 units |

## Electrical Characteristics $T_A$ = 25°C unless otherwise noted

| Symbol | Parameter | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Off Characteristics** | | | | | | |
| $B_{VDSS}$ | Drain to Source Breakdown Voltage | $I_D$ = 250μA, $V_{GS}$ = 0V | 60 | - | - | V |
| $I_{DSS}$ | Zero Gate Voltage Drain Current | $V_{DS}$ = 50V, $V_{GS}$ = 0V | - | - | 1 | μA |
| | | $V_{DS}$ = 50V, $V_{GS}$ = 0V, $T_A$ = 150°C | - | - | 250 | μA |
| $I_{GSS}$ | Gate to Source Leakage Current | $V_{GS}$ = ±16V | - | - | ±100 | nA |
| **On Characteristics** | | | | | | |
| $V_{GS(TH)}$ | Gate to Source Threshold Voltage | $V_{GS}$ = $V_{DS}$, $I_D$ = 250μA | 1 | - | 3 | V |
| $r_{DS(ON)}$ | Drain to Source On Resistance | $I_D$ = 5.1A, $V_{GS}$ = 10V | - | 0.041 | 0.049 | Ω |
| | | $I_D$ = 4.8A, $V_{GS}$ = 5V | - | 0.048 | 0.056 | Ω |
| | | $I_D$ = 4.8A, $V_{GS}$ = 5V, $T_A$ = 150°C | - | 0.091 | 0.106 | Ω |
| **Dynamic Characteristics** | | | | | | |
| $C_{ISS}$ | Input Capacitance | $V_{DS}$ = 25V, $V_{GS}$ = 0V, f = 1MHz | - | 620 | - | pF |
| $C_{OSS}$ | Output Capacitance | | - | 180 | - | pF |
| $C_{RSS}$ | Reverse Transfer Capacitance | | - | 30 | - | pF |
| $Q_{g(TOT)}$ | Total Gate Charge at 10V | $V_{GS}$ = 0V to 10V; $V_{DD}$ = 30V, $I_D$ = 4.8A, $I_g$ = 1.0mA | | 18 | 23 | nC |
| $Q_{g(5)}$ | Total Gate Charge at 5V | $V_{GS}$ = 0V to 5V; $V_{DD}$ = 30V, $I_D$ = 4.8A, $I_g$ = 1.0mA | - | 10 | 13 | nC |
| $Q_{g(TH)}$ | Threshold Gate Charge | $V_{GS}$ = 0V to 1V; $V_{DD}$ = 30V, $I_D$ = 4.8A, $I_g$ = 1.0mA | - | 0.6 | 0.8 | nC |
| $Q_{gs}$ | Gate to Source Gate Charge | $V_{DD}$ = 30V, $I_D$ = 4.8A, $I_g$ = 1.0mA | - | 1.8 | - | nC |
| $Q_{gd}$ | Gate to Drain “Miller” Charge | $V_{DD}$ = 30V, $I_D$ = 4.8A, $I_g$ = 1.0mA | - | 5 | - | nC |
| **Switching Characteristics** ($V_{GS}$ = 5V) | | | | | | |
| $t_{ON}$ | Turn-On Time | $V_{DD}$ = 30V, $I_D$ = 1A, $V_{GS}$ = 5V, $R_{GS}$ = 16Ω | - | - | 44 | ns |
| $t_{d(ON)}$ | Turn-On Delay Time | | - | 10 | - | ns |
| $t_r$ | Rise Time | | - | 19 | - | ns |
| $t_{d(OFF)}$ | Turn-Off Delay Time | | - | 45 | - | ns |
| $t_f$ | Fall Time | | - | 27 | - | ns |
| $t_{OFF}$ | Turn-Off Time | | - | - | 108 | ns |
| **Drain-Source Diode Characteristics** | | | | | | |
| $V_{SD}$ | Source to Drain Diode Voltage | $I_{SD}$ = 4.8A | - | - | 1.25 | V |
| | | $I_{SD}$ = 2.4A | - | - | 1.0 | V |
| $t_{rr}$ | Reverse Recovery Time | $I_{SD}$ = 4.8A, $dI_{SD}/dt$ = 100A/μs | - | - | 43 | ns |
| $Q_{RR}$ | Reverse Recovered Charge | $I_{SD}$ = 4.8A, $dI_{SD}/dt$ = 100A/μs | - | - | 55 | nC |

**Notes:**
**1:** Starting $T_J$ = 25°C, L = 20mH, $I_{AS}$ = 5.1A
**2:** $R_{\theta JA}$ is 50 °C/W when mounted on a 0.5 $in^2$ copper pad on FR-4 at 1 second.
**3:** $R_{\theta JA}$ is 191 °C/W when mounted on a 0.027 $in^2$ copper pad on FR-4 at 1000 seconds.
**4:** $R_{\theta JA}$ is 228 °C/W when mounted on a 0.006 $in^2$ copper pad on FR-4 at 1000 seconds.

## Typical Characteristics $T_A$ = 25°C unless otherwise noted

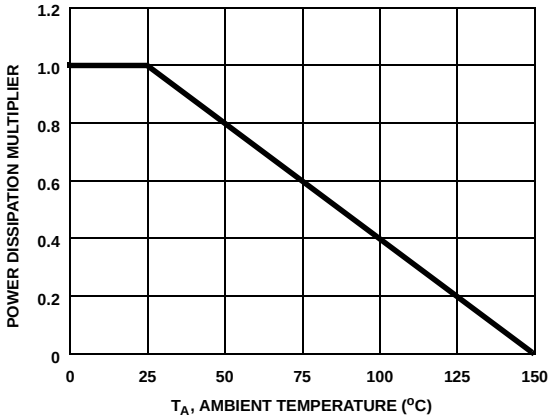



**Figure 1. Normalized Power Dissipation vs Ambient Temperature**

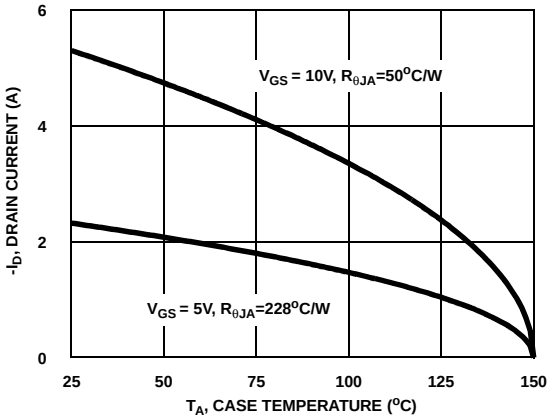



**Figure 2. Maximum Continuous Drain Current vs Case Temperature**

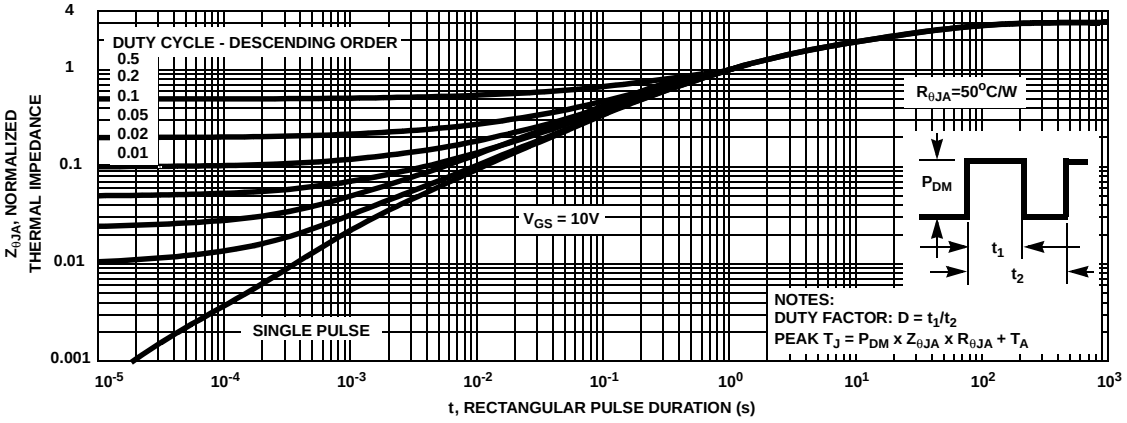



**Figure 3. Normalized Maximum Transient Thermal Impedance**

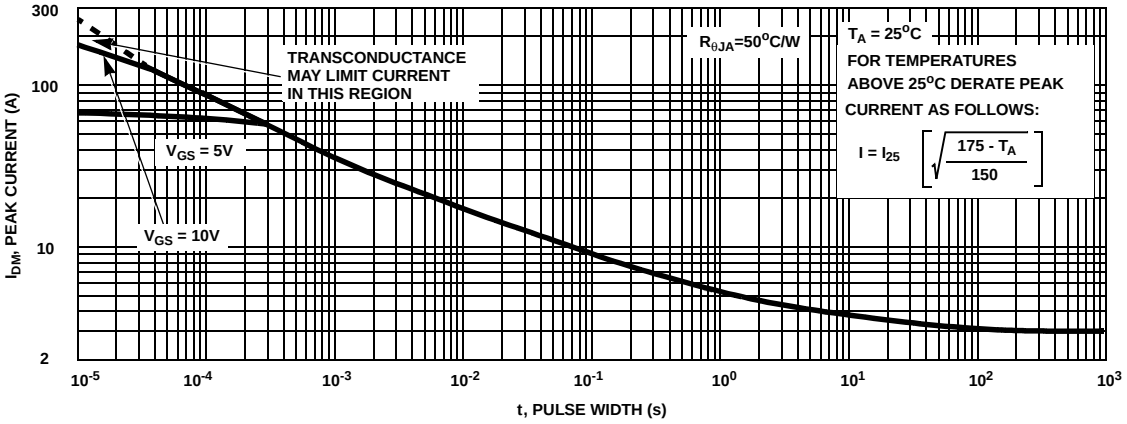



**Figure 4. Peak Current Capability**

## Typical Characteristics $T_A$ = 25°C unless otherwise noted

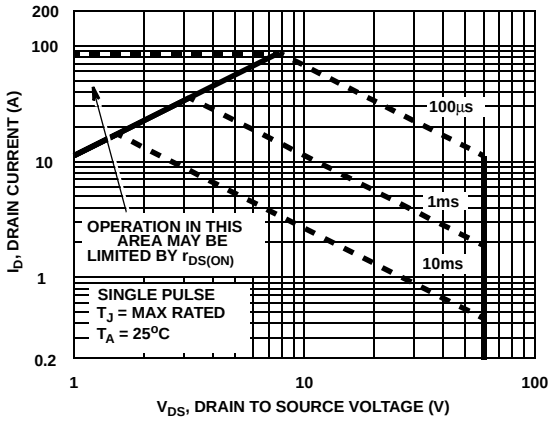



**Figure 5. Forward Bias Safe Operating Area**

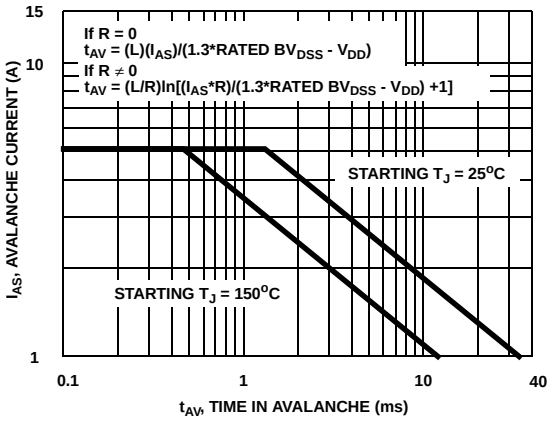



**Figure 6. Unclamped Inductive Switching Capability**

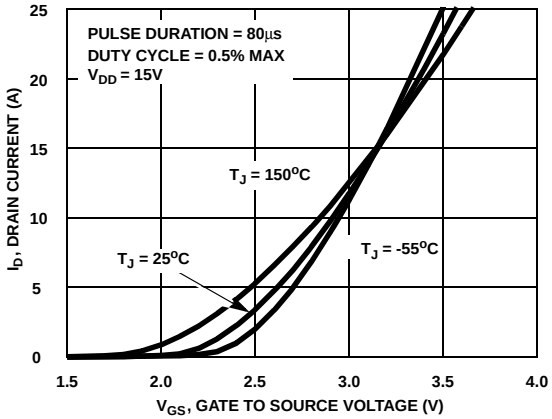



**Figure 7. Transfer Characteristics**

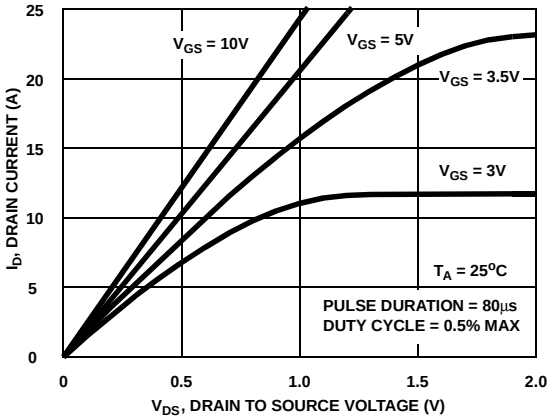



**Figure 8. Saturation Characteristics**

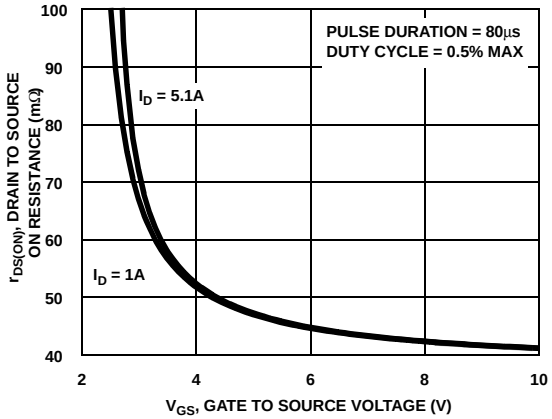



**Figure 9. Drain to Source On Resistance vs Gate Voltage and Drain Current**

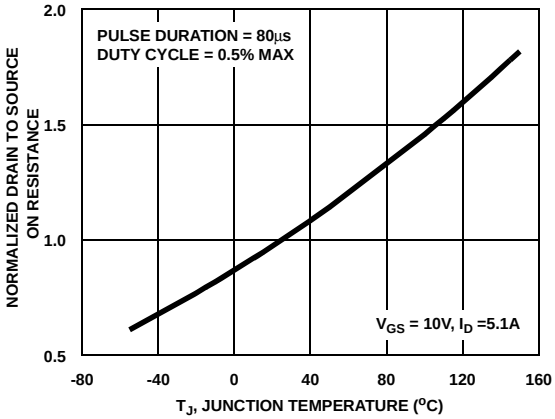



**Figure 10. Normalized Drain to Source On Resistance vs Junction Temperature**

## Typical Characteristics $T_A$ = 25°C unless otherwise noted

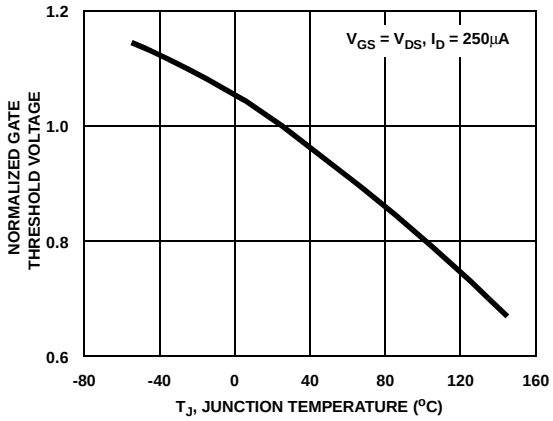



**Figure 11. Normalized Gate Threshold Voltage vs Junction Temperature**

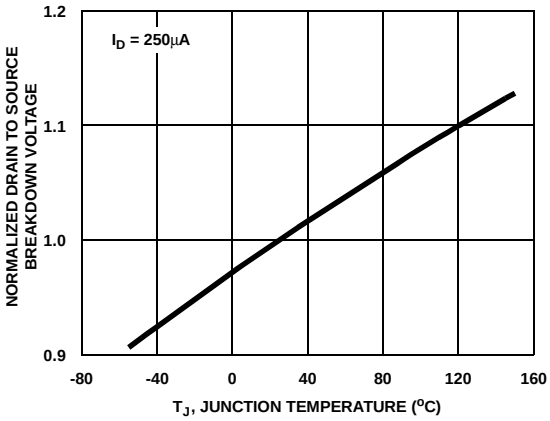



**Figure 12. Normalized Drain to Source Breakdown Voltage vs Junction Temperature**

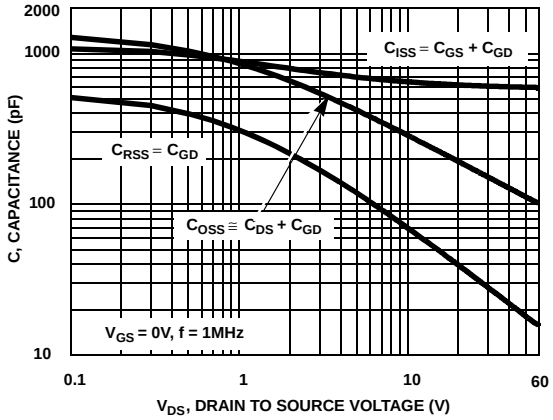



**Figure 13. Capacitance vs Drain to Source Voltage**

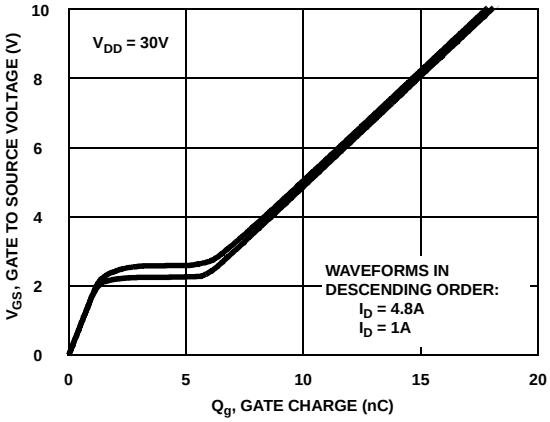



**Figure 14. Gate Charge Waveforms for Constant Gate Currents**

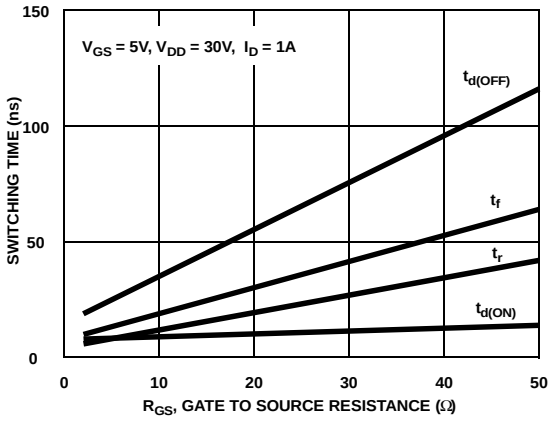



**Figure 15. Switching Time vs Gate Resistance**

## Test Circuits and Waveforms

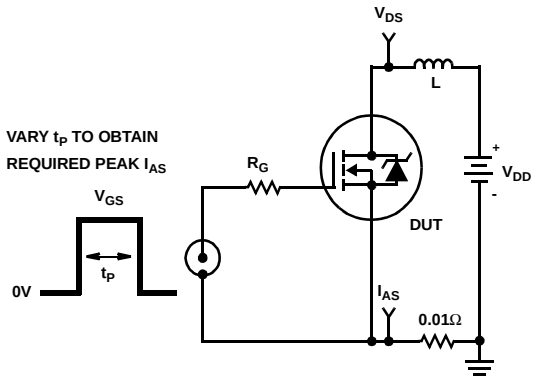



Figure 16. Unclamped Energy Test Circuit

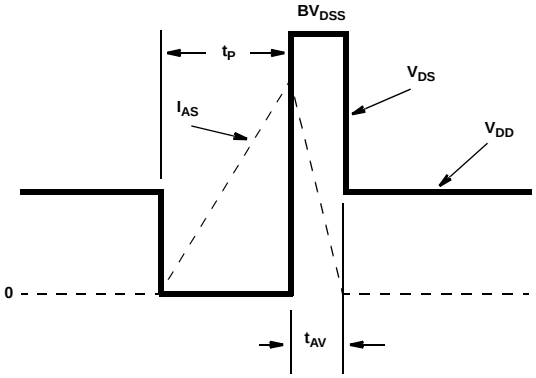



Figure 17. Unclamped Energy Waveforms

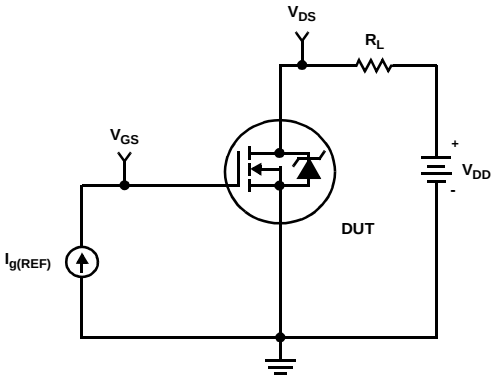



Figure 18. Gate Charge Test Circuit

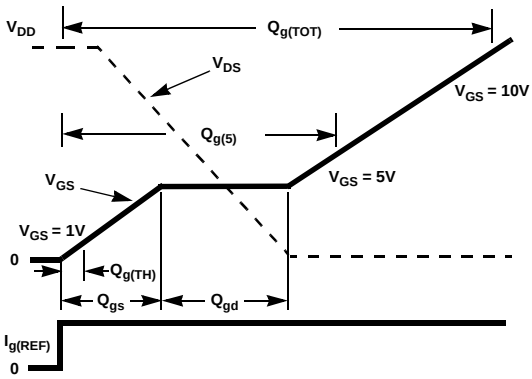



Figure 19. Gate Charge Waveforms

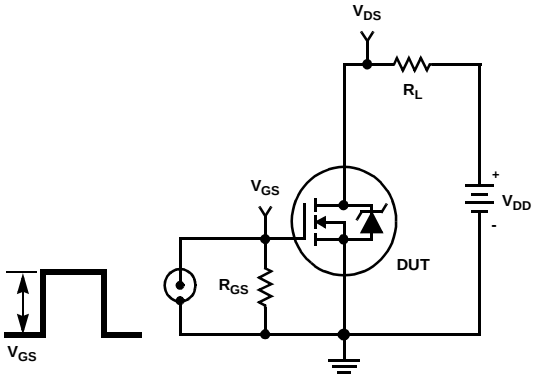



Figure 20. Switching Time Test Circuit

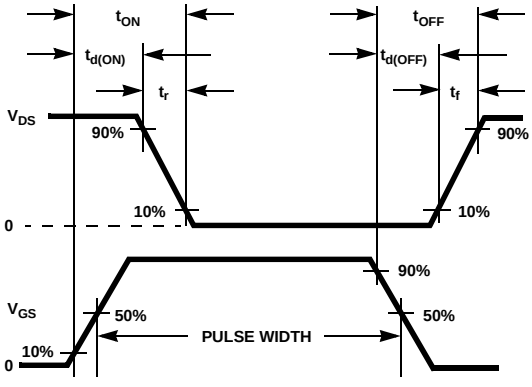



Figure 21. Switching Time Waveforms

## Thermal Resistance vs. Mounting Pad Area

The maximum rated junction temperature, $T_{JM}$, and the thermal resistance of the heat dissipating path determines the maximum allowable device power dissipation, $P_{DM}$, in an application. Therefore the application's ambient temperature, $T_A$ ($^oC$), and thermal resistance $R_{\theta JA}$ ($^oC/W$) must be reviewed to ensure that $T_{JM}$ is never exceeded. Equation 1 mathematically represents the relationship and serves as the basis for establishing the rating of the part.

$$P_{DM} = \frac{(T_{JM} - T_A)}{R_{\theta JA}} \quad \text{(EQ. 1)}$$

In using surface mount devices such as the SO-8 package, the environment in which it is applied will have a significant influence on the part's current and maximum power dissipation ratings. Precise determination of $P_{DM}$ is complex and influenced by many factors:

1. Mounting pad area onto which the device is attached and whether there is copper on one side or both sides of the board.
2. The number of copper layers and the thickness of the board.
3. The use of external heat sinks.
4. The use of thermal vias.
5. Air flow and board orientation.
6. For non steady state applications, the pulse width, the duty cycle and the transient thermal response of the part, the board and the environment they are in.

Fairchild provides thermal information to assist the designer's preliminary application evaluation. Figure 22 defines the $R_{\theta JA}$ for the device as a function of the top copper (component side) area. This is for a horizontally positioned FR-4 board with 1oz copper after 1000 seconds of steady state power with no air flow. This graph provides the necessary information for calculation of the steady state junction temperature or power dissipation. Pulse applications can be evaluated using the Fairchild device Spice thermal model or manually utilizing the normalized maximum transient thermal impedance curve.

Thermal resistances corresponding to other copper areas can be obtained from Figure 22 or by calculation using Equation 2. The area, in square inches is the top copper area including the gate and source pads.

$$R_{\theta JA} = 103.2 - 24.3\ln(Area) \quad \text{(EQ. 2)}$$

The dual die SO-8 package introduces an additional thermal coupling resistance, $R_{\theta B}$. Equation 3 describes $R_{\theta B}$ as a function of the top copper mouting pad area.

$$R_{\theta B} = 46.4 - 21.7\ln(Area) \quad \text{(EQ. 3)}$$

The thermal coupling resistance vs. copper area is also graphically depicted in Figure 22.

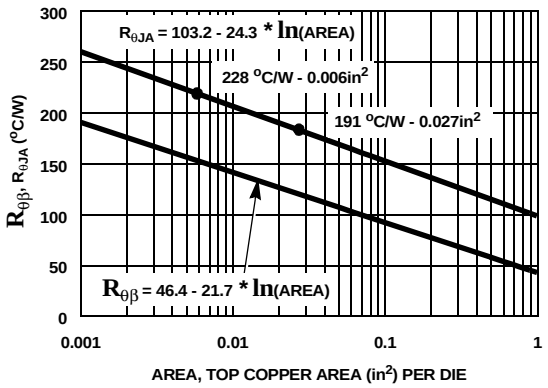
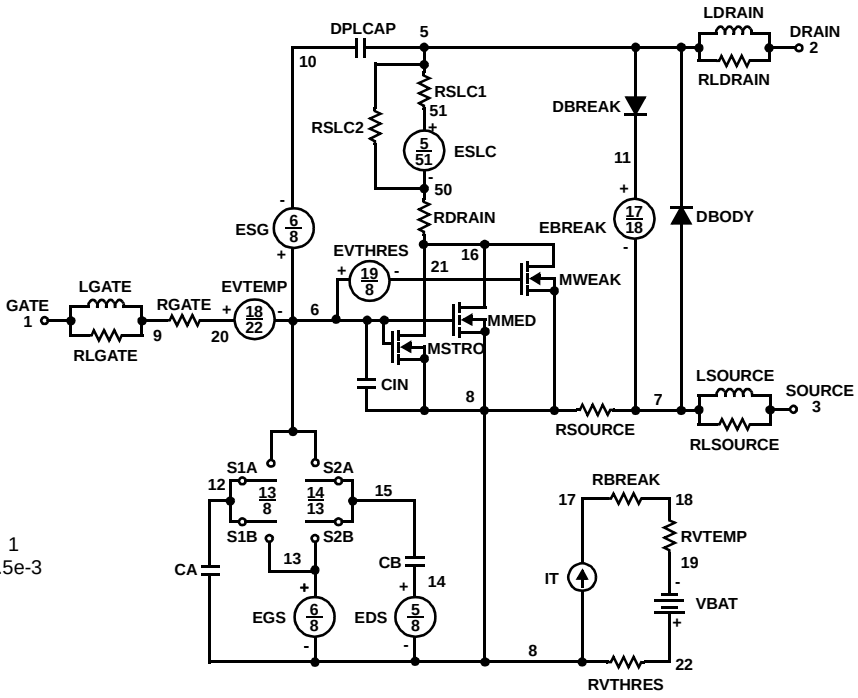



**Figure 22. Thermal Resistance vs Mounting Pad Area**

## PSPICE Electrical Model

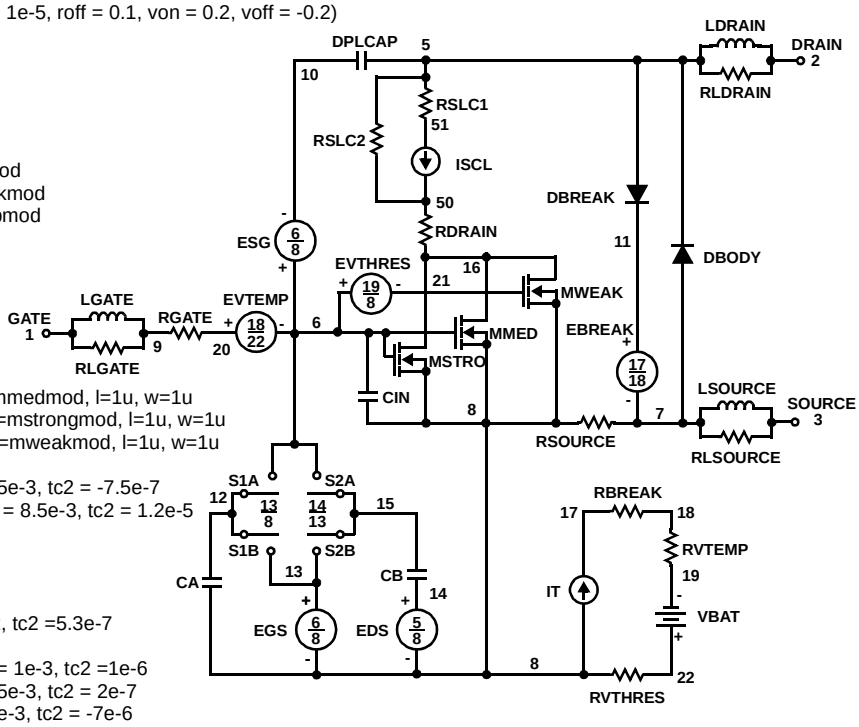
```
.SUBCKT HUFA76413DK8T 2 1 3 ;       rev April 2002
CA  12  8 7.8e-10
CB  15  14 9.8e-10
CIN  6  8 5.8e-10

DBODY 7 5 DBODYMOD
DBREAK 5 11  DBREAKMOD
DPLCAP 10 5 DPLCAPMOD

EBREAK 11 7 17  18 67.4
EDS  14  8  5  8 1
EGS  13  8  6  8 1
ESG 6 10 6 8 1
EVTHRES 6 21 19 8  1
EVTEMP 20 6 18 22 1

IT  8  17  1

LDRAIN 2 5 1e-9
LGATE 1  9 1.34e-9
LSOURCE  3  7 0.59e-9

MMED 16 6 8 8 MMEDMOD
MSTRO 16 6 8 8 MSTROMOD
MWEAK 16 21 8 8 MWEAKMOD

RBREAK  17  18  RBREAKMOD  1
RDRAIN 50 16 RDRAINMOD 22.5e-3
RGATE  9  20 2.2
RLDRAIN 2 5 10
RLGATE 1 9 13.4
RLSOURCE 3 7 5.9
RSLC1 5 51 RSLCMOD 1e-6
RSLC2 5 50 1e3
RSOURCE  8  7  RSOURCEMOD 15.3e-3
RVTHRES 22 8 RVTHRESMOD  1
RVTEMP 18 19 RVTEMPMOD 1

S1A  6  12  13  8  S1AMOD
S1B  13  12  13  8  S1BMOD
S2A  6  15  14  13  S2AMOD
S2B  13  15  14  13  S2BMOD

VBAT 22 19  DC  1

ESLC 51 50 VALUE={(V(5,51)/ABS(V(5,51)))*(PWR(V(5,51)/(1e-6*180),2.5))}

.MODEL DBODYMOD D (IS = 8e-13  RS = 1.58e-2  TRS1 = 1e-3  TRS2 = 3e-6  XTI=3.2  CJO = 8e-10  TT = 3.2e-8  M = 0.54)
.MODEL DBREAKMOD D (RS = 1.18  TRS1 = 2e-3  TRS2 = -2.6e-5)
.MODEL DPLCAPMOD D (CJO = 5.7e-10 IS = 1e-30 N = 10 M = 0.87)
.MODEL MMEDMOD NMOS (VTO = 1.68 KP = 2 IS =1e-30 N = 10 TOX = 1 L = 1u W = 1u RG = 2.2)
.MODEL MSTROMOD NMOS (VTO = 2.05 KP =35 IS = 1e-30 N = 10 TOX = 1 L = 1u  W = 1u)
.MODEL MWEAKMOD NMOS (VTO = 1.48 KP = 0.04 IS = 1e-30 N = 10 TOX = 1 L = 1u W = 1u RG = 22 RS = 0.1)
.MODEL RBREAKMOD RES (TC1 = 1.15e-3 TC2 = -7.5e-7)
.MODEL RDRAINMOD RES (TC1 = 8.5e-3  TC2 = 1.2e-5)
.MODEL RSLCMOD RES (TC1 = 3e-2 TC2 = 5.3e-7)
.MODEL RSOURCEMOD RES (TC1 = 1e-3 TC2 = 1e-6)
.MODEL RVTHRESMOD RES (TC1 = -1.4e-3 TC2 = -7e-6)
.MODEL RVTEMPMOD RES (TC1 = -1.5e-3  TC2 = 2e-7)

.MODEL S1AMOD VSWITCH (RON = 1e-5  ROFF = 0.1  VON = -5.0  VOFF= -1.0)
.MODEL S1BMOD VSWITCH (RON = 1e-5  ROFF = 0.1  VON = -1.0  VOFF= -5.0)
.MODEL S2AMOD VSWITCH (RON = 1e-5  ROFF = 0.1  VON = -0.2  VOFF= 0.2)
.MODEL S2BMOD VSWITCH (RON = 1e-5  ROFF = 0.1  VON = 0.2  VOFF= -0.2)

.ENDS
```




Note: For further discussion of the PSPICE model, consult **A New PSPICE Sub-Circuit for the Power MOSFET Featuring Global Temperature Options**; IEEE Power Electronics Specialist Conference Records, 1991, written by William J. Hepp and C. Frank Wheatley.

## SABER Electrical Model

```
REV April 2002
template HUFA76413DK8T n2,n1,n3
electrical n2,n1,n3
{
var i iscl
dp..model dbodymod =  (isl = 8e-13, rs = 1.58e-2, trs1 = 1e-3, trs2 = 3e-6, xti = 3.2, cjo = 8e-10, tt = 3.2e-8, m = 0.54)
dp..model dbreakmod = (rs = 1.18, trs1 = 2e-3, trs2 = -2.6e-5)
dp..model dplcapmod =  (cjo = 5.7e-10, isl =10e-30, nl =10, m = 0.87)
m..model mmedmod = (type=_n, vto = 1.68, kp = 2, is =1e-30, tox=1)
m..model mstrongmod = (type=_n, vto = 2.05, kp = 35, is = 1e-30, tox = 1)
m..model mweakmod = (type=_n, vto = 1.48, kp = 0.04, is = 1e-30, tox = 1, rs=0.1)
sw_vcsp..model s1amod =  (ron = 1e-5, roff = 0.1, von = -5.0, voff = -1.0)
sw_vcsp..model s1bmod =  (ron =1e-5, roff = 0.1, von = -1.0, voff = -5.0)
sw_vcsp..model s2amod =  (ron = 1e-5, roff = 0.1, von = -0.2, voff = 0.2)
sw_vcsp..model s2bmod =  (ron = 1e-5, roff = 0.1, von = 0.2, voff = -0.2)

c.ca n12 n8 = 7.8e-10
c.cb n15 n14 = 9.8e-10
c.cin n6 n8 = 5.8e-10

dp.dbody n7 n5 = model=dbodymod
dp.dbreak n5 n11 = model=dbreakmod
dp.dplcap n10 n5 = model=dplcapmod

i.it n8 n17 = 1

l.ldrain n2 n5 = 1e-9
l.lgate n1 n9 = 1.34e-9
l.lsource n3 n7 = 0.59e-9

m.mmed n16 n6 n8 n8 = model=mmedmod, l=1u, w=1u
m.mstrong n16 n6 n8 n8 = model=mstrongmod, l=1u, w=1u
m.mweak n16 n21 n8 n8 = model=mweakmod, l=1u, w=1u

res.rbreak n17 n18  = 1, tc1 = 1.15e-3, tc2 = -7.5e-7
res.rdrain n50 n16  = 22.5e-3, tc1 = 8.5e-3, tc2 = 1.2e-5
res.rgate n9 n20 = 2.2
res.rldrain n2 n5 = 10
res.rlgate n1 n9 = 13.4
res.rlsource n3 n7 = 5.9
res.rslc1 n5 n51= 1e-6, tc1 = 3e-2, tc2 =5.3e-7
res.rslc2 n5 n50 = 1e3
res.rsource n8 n7  = 15.3e-3, tc1 = 1e-3, tc2 =1e-6
res.rvtemp n18 n19  = 1, tc1 = -1.5e-3, tc2 = 2e-7
res.rvthres n22 n8  = 1, tc1 = -1.4e-3, tc2 = -7e-6

spe.ebreak n11 n7 n17 n18 = 67.4
spe.eds n14 n8 n5 n8 = 1
spe.egs n13 n8 n6 n8 = 1
spe.esg n6 n10 n6 n8 = 1
spe.evtemp n20 n6 n18 n22 = 1
spe.evthres n6 n21 n19 n8 = 1

sw_vcsp.s1a n6 n12 n13 n8 = model=s1amod
sw_vcsp.s1b n13 n12 n13 n8 = model=s1bmod
sw_vcsp.s2a n6 n15 n14 n13 = model=s2amod
sw_vcsp.s2b n13 n15 n14 n13 = model=s2bmod

v.vbat n22 n19 = dc=1

equations {
i (n51->n50) +=iscl
iscl: v(n51,n50) = ((v(n5,n51)/(1e-9+abs(v(n5,n51))))*((abs(v(n5,n51)*1e6/180))** 2.5))
}
}
```



## SPICE Thermal Model

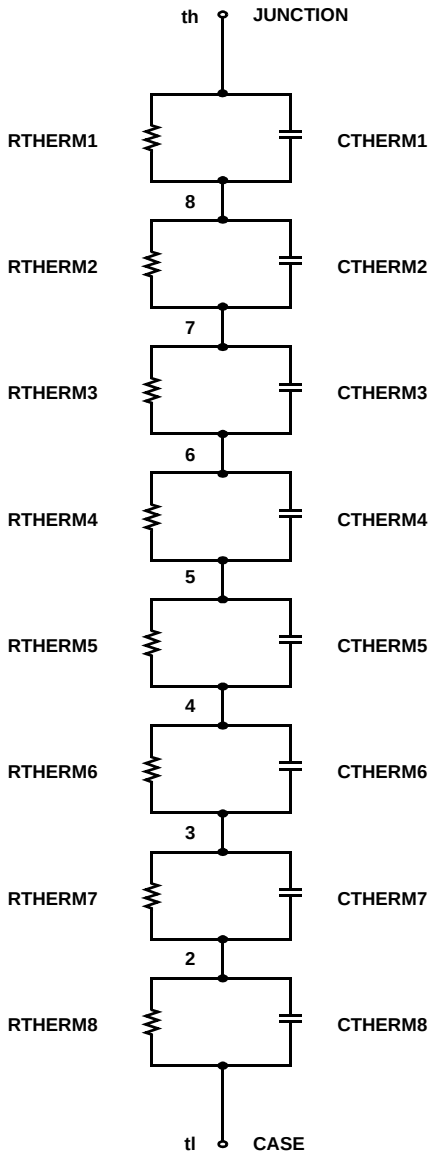
REV April 2002
HUFA76413DK8T
Copper Area = 0.493in$^2$

```
CTHERM1 th 8 8.5e-4
CTHERM2 8 7 1.8e-3
CTHERM3 7 6 5.0e-3
CTHERM4 6 5 1.3e-2
CTHERM5 5 4 4.0e-2
CTHERM6 4 3 1.5e-1
CTHERM7 3 2 7.5e-1
CTHERM8 2 tl 3

RTHERM1 th 8 3.5e-2
RTHERM2 8 7 6.0e-1
RTHERM3 7 6 2
RTHERM4 6 5 8
RTHERM5 5 4 18
RTHERM6 4 3 20
RTHERM7 3 2 23
RTHERM8 2 tl 25
```

## SABER Thermal Model

SABER thermal model HUFA76413DK8T
Copper Area = 0.493in$^2$

```
template thermal_model th tl
thermal_c th, tl
{
ctherm.ctherm1 th 8 =8.5e-4
ctherm.ctherm2 8 7 =1.8e-3
ctherm.ctherm3 7 6 =5.0e-3
ctherm.ctherm4 6 5 =1.3e-2
ctherm.ctherm5 5 4 =4.0e-2
ctherm.ctherm6 4 3 =1.5e-1
ctherm.ctherm7 3 2 =7.5e-1
ctherm.ctherm8 2 tl =3

rtherm.rtherm1 th 8 =3.5e-2
rtherm.rtherm2 8 7 =6.0e-1
rtherm.rtherm3 7 6 =2
rtherm.rtherm4 6 5 =8
rtherm.rtherm5 5 4 =18
rtherm.rtherm6 4 3 =20
rtherm.rtherm7 3 2 =23
rtherm.rtherm8 2 tl =25
}
```



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